Genetic Algorithm Aerodynamic Shape Optimization

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The objective of this work was to explore the use of genetic algorithms in performing optimizations on engineering and science problems of importance to NASA. In particular, a method for aerodynamic shape-optimization using a genetic algorithm (GA) has been developed and used to optimize a number of aerodynamic shapes. In contrast to gradient-based methods, design-space-search methods such as GAs offer an alternative approach with several attractive features.

The basic idea associated with the GA approach was to search for optimal solutions using an analogy to the theory of evolution. During solution iteration (or "evolution" using GA terminology) the decision variables or "genes" are manipulated using various operators to create new design populations, that is, new sets of "chromosomes." Once established, each new design or chromosome is evaluated using an objective-like "biological fitness function" to determine survivability. The fittest individuals are retained and evolve while the least fit individuals die off.

Constraints can easily be included in this approach either by direct inclusion in the fitness function or by preprocessing the candidate design. For example, if a design violates a constraint, its fitness is set to zero, that is, it does not survive to the next evolution level. Because GA optimization is not a gradient-based optimization technique, it does not need sensitivity derivatives; theoretically, it works well in non-smooth design spaces containing several, or perhaps many, local extrema. It is also an attractive method for multi-objective design applications, offering the ability to compute simultaneous optimal solution sets instead of the limited single-design-point approach traditionally employed by other methods.

Computational results demonstrating the use of GA optimization are presented in figures 1(a) and 1(b) for a typical transonic wing. The design space discretization for this wing optimization problem consists of 10 free parameters, or genes. Eight of the genes are associated with the wing upper-surface thickness—four thickness variables at two span

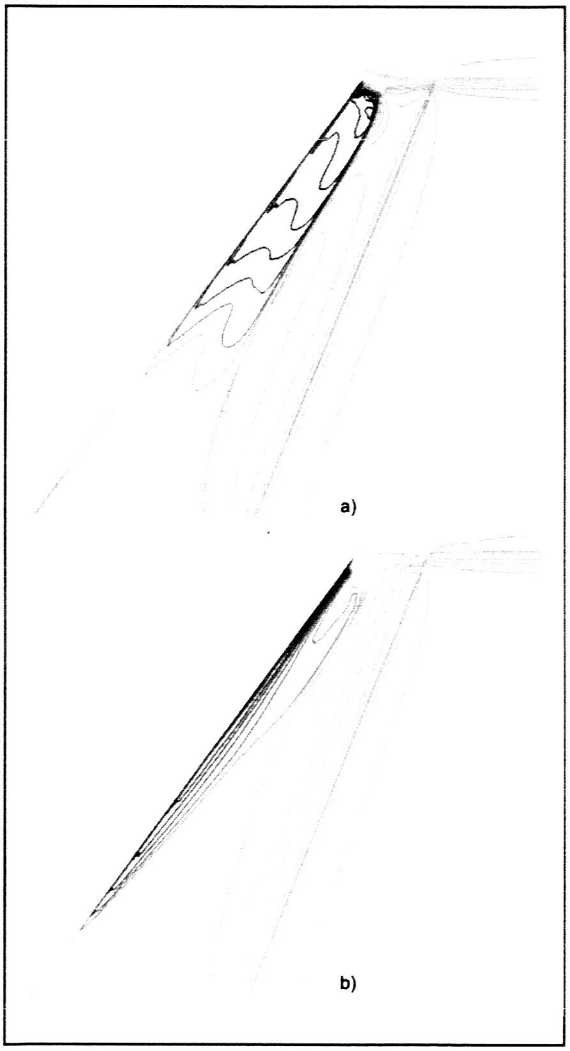

Fig. 1. Mach number contours plotted on the upper wing surface. (a) Baseline solution; (b) optimized solution.

stations each, wing root and tip. The value of wing twist at the root and tip are the two remaining genes. In this optimization, different gene combinations are sought to optimize the wing's lift-to-drag ratio with a constraint on lift.

Figures 1(a) and 1(b) show Mach number contours from the upper wing surface before and after optimization. Note that the optimization has produced a solution with significantly reduced shock strength, especially on the outboard part of the wing. In addition, the single-shock characteristic of the baseline solution has been replaced with a weaker two-shock pattern in the optimized solution. For this optimization, the lift-to-drag function was increased by 14.7% and the drag was reduced by 34%.

Figure 2 presents the effect of population size, that is, the number of chromosomes used, on GA convergence in terms of the number of function evaluations (that is, number of wing flow solutions). The four curves correspond to GA optimizations that utilize 10, 20, 50, and 100 chromosomes, respectively. For this 10-gene problem it is clear that the use of a smaller number of chromosomes (10–20) produces superior GA convergence, which is achieved in about 500 function evaluations. The 50-chromosome case is only slightly inferior, but the 100-chromosome case is significantly slower.

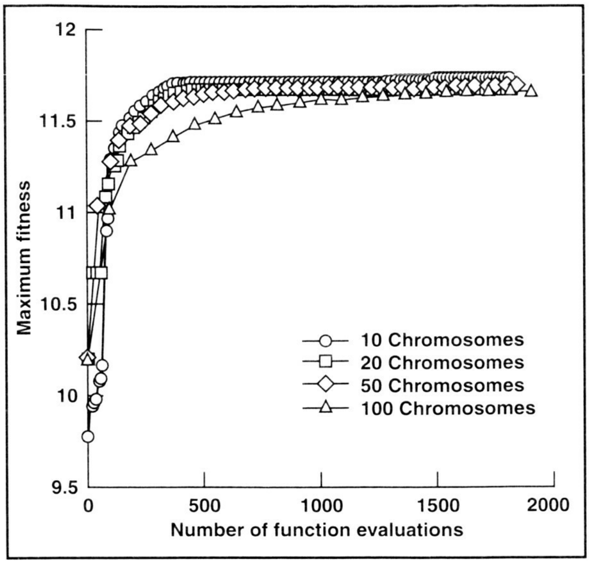

Fig. 2. Effect of number of chromosomes on GA performance.

A GA procedure suitable for performing aerodynamic shape optimizations has been developed. Results indicate that the GA is easy to implement, flexible in application, and extremely reliable, being relatively insensitive to design space noise.

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Contributors to Three-Dimensional Perception of Sound

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A study was conducted to evaluate the role of individualized head-related transfer functions (HRTF) for localization accuracy and the experience of realism in using auditory displays. Realistic auditory displays that emulate free-field auditory sound sources are required for the efficient and effective design of virtual reality systems for real-world applications, including teleconferencing and interacting with virtual systems. A number of studies have evaluated humans' abilities to localize aural signals delivered via headphones in a virtual space. The results suggest that optimal localization performance and perceived realism result from inclusion of factors that emulate those typical of everyday spatial hearing experiences (for example, head position effects, a realistically diffuse field or